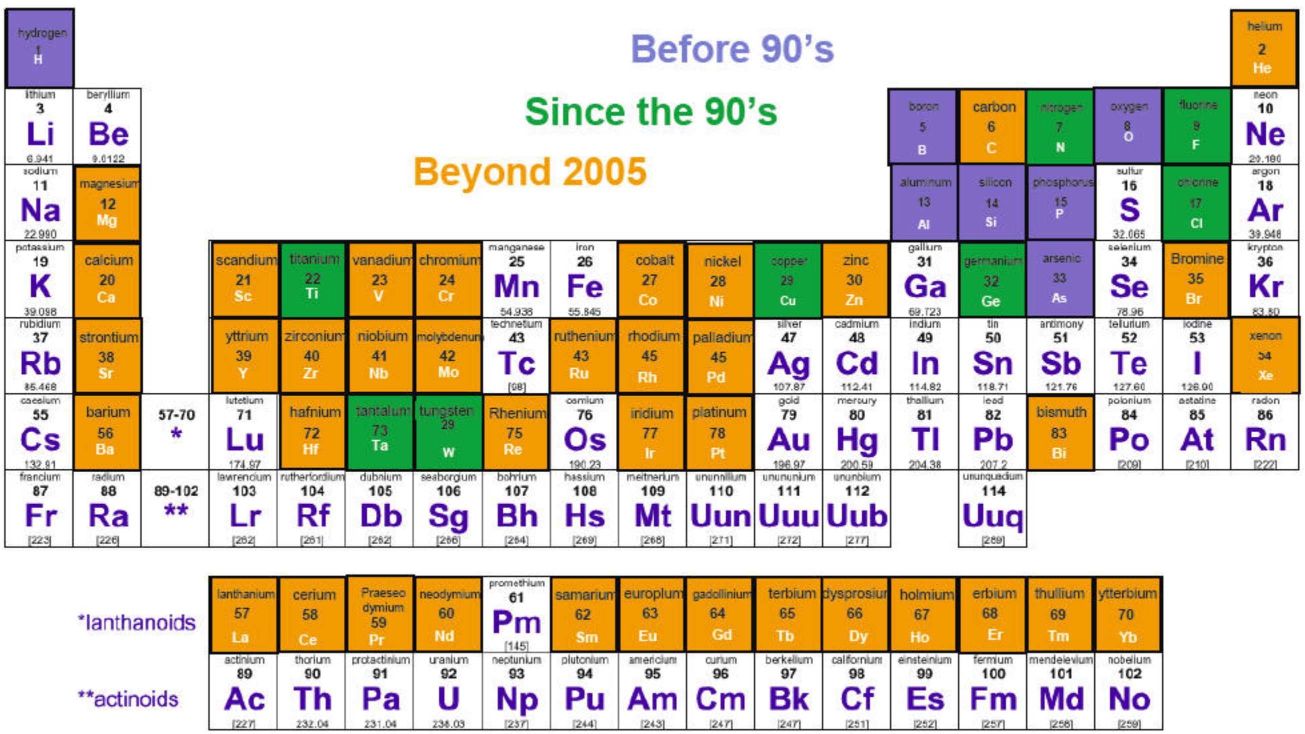
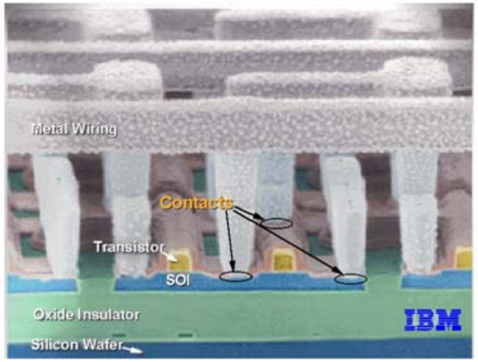
New Materials Innovations in CMOS Devices

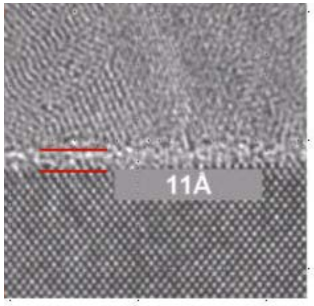
- Elements Employed in Silicon Technology



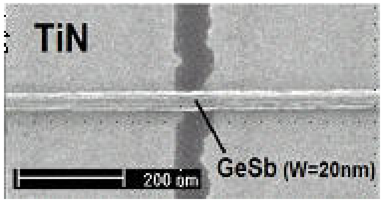
- New materials and smaller features drive need for characterization techniques
- Need compositional and electrical information at device dimensions

IBM at NSLS-I

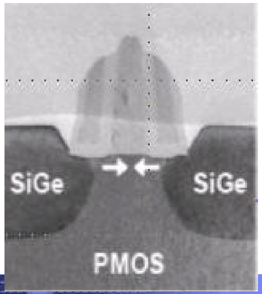




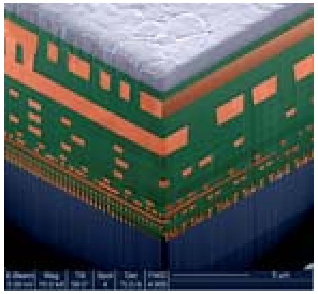
- ***in-situ* real-time annealing effects**
  - phase formation in silicides
  - diffusion barrier failure T
  - solder formation
  - crystallization of phase-change materials
- **phase identification (GIXD)**
  - high-κ dielectric ultra-thin films, intermetallics, phase-change materials, silicides
- **texture and grain size (pole figures, GIXD, HRXRD)**
  - axiotaxy in silicides and germanides, Cu features (interconnects)



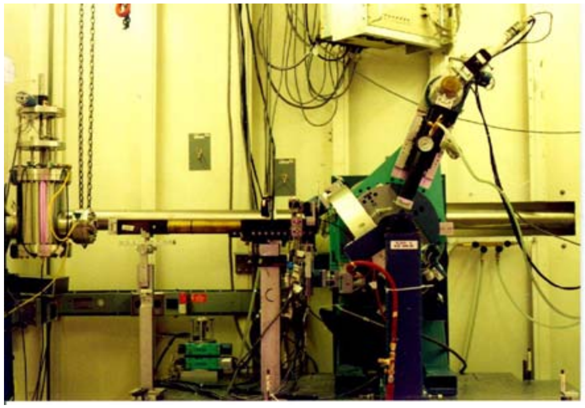
- **surface and interface quality (XRR)**
  - dielectrics, silicides, phase-change materials, etc.
- **strain in thin films and features (HRXRD, microdiffraction)**
  - SiGe/Si, Si:C/Si, etc.

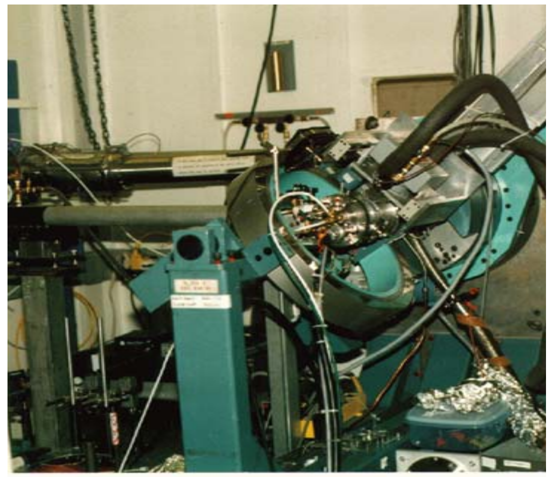


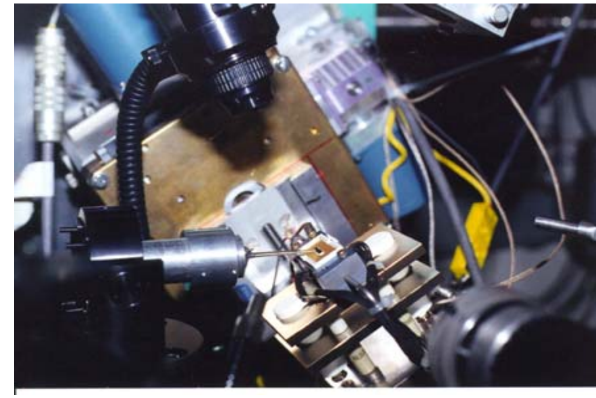
to understand and improve materials and processes used in making devices



Endstation instrumentation at X20







"Standard" diffraction

- Standard diffraction
- Triple-axis diffraction
- Reflectivity
- GIXD
- SAXS
- Four-circle Huber used for pole figures, reflectivity, structure ID, strain relaxation, etc.

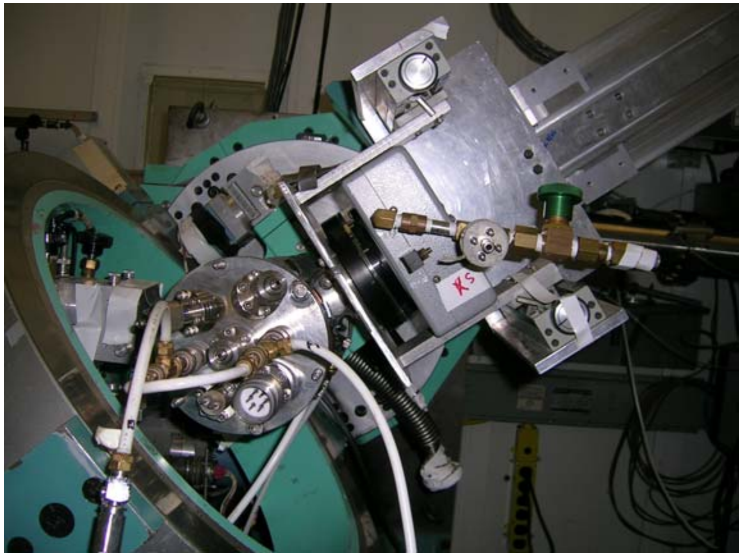
Time-resolved scattering

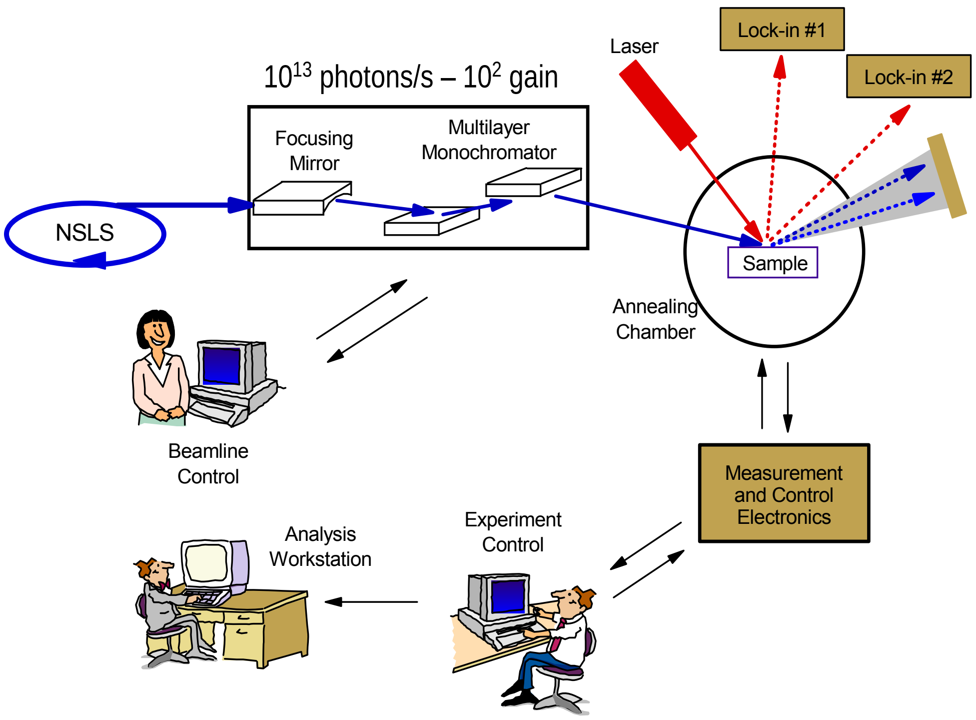
- High temp. annealing chamber
- Diffraction into fast linear or area detector
- Resistance and optical scattering
- Used with multilayer monochromator for *in-situ* measurements of phase transformations, barrier failures, kinetics, texture evolution.

Microdiffraction

- Standard diffraction
- Fluorescence
- Heating/electrical stage
- Used for diffraction topography, grain or local tilt and mosaic, elemental mapping.

Time-resolved *in-situ* XRD, resistance and light scattering

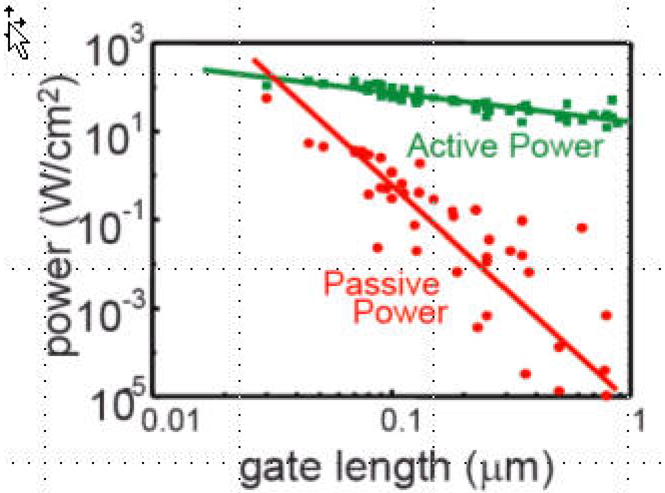




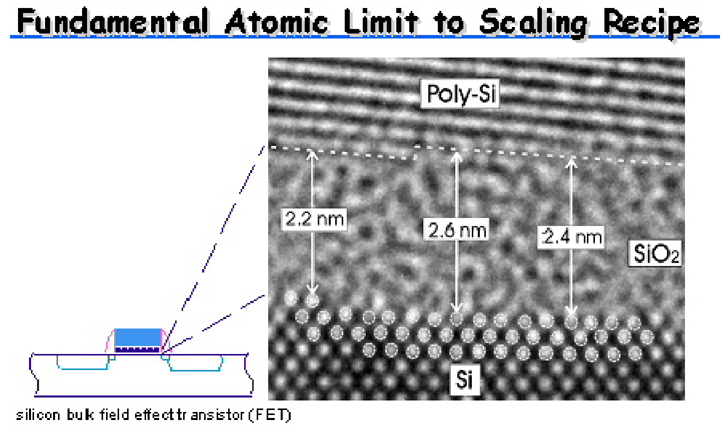
- **Fast data collection and analysis**
- **Intense signal**
  - **Transformation temps**
  - **Morphology changes**
  - **Kinetics**
- **Quick evaluation of large array of variables**
  - **processes parameters**
  - **film thicknesses**
  - **dopants**
- **Size effects**

limitations:
- ***detector***
- ***reciprocal space access***
- ***sample turnaround***
- ***?***

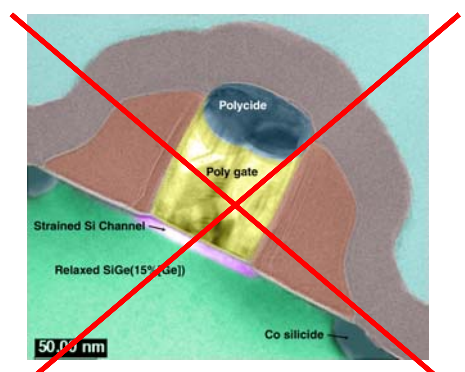
What will microelectronics look like in 8 years?

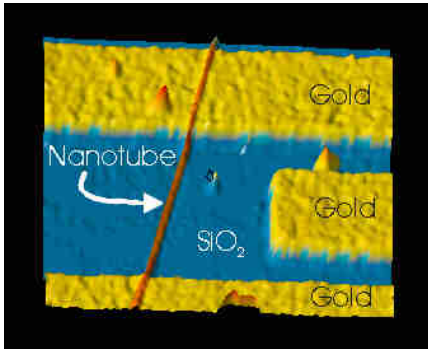


- **Gate Oxide no longer scales:**
  - –Need to reduce gate leakage
  - –Power Density increases-more transistors with constant power
  - –Power constant - Gate can not turn off channel effectively if gate oxide is increased



Oxide thickness is approaching a few atomic layers





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As long as IBM makes hardware, we'll need materials and process analysis…

IBM Needs at NSLS-II

- High-throughput/rapid access very important:
  - **phase ID, texture, failures, phase formation, process variables**
- **Guaranteed** access to high-throughput time/temp-resolved XRD
- Access to thin film analysis techniques
  - GIXD, texture, XRR, Bragg-Brentano, etc.
- Access to micro/nano diffraction
- Possible access to:
  - nanotomography (Xradia full-field microscope?)
  - EXAFS
  - PDF?
- Minimum time gap in access between NSLS and NSLS-II

Tentative plans

- **Upgrade of high-throughput TR endstation on X20C (in stages):**
  - dome for more reciprocal space access
  - special diffractometer
  - RTA heater and laser annealing capabilities
  - ports for adding probes
  - area, linear and point detectors
  - automated sample changing
  - automated evacuation and ambient control
  - remote access
- **New 6-circle for X20A**
- **Move both to NSLS-II**
- **If you are interested, send email to JLJ@BNL.GOV**